Sustained and Targeted Ocean Observations for Hurricane Research and Forecasts

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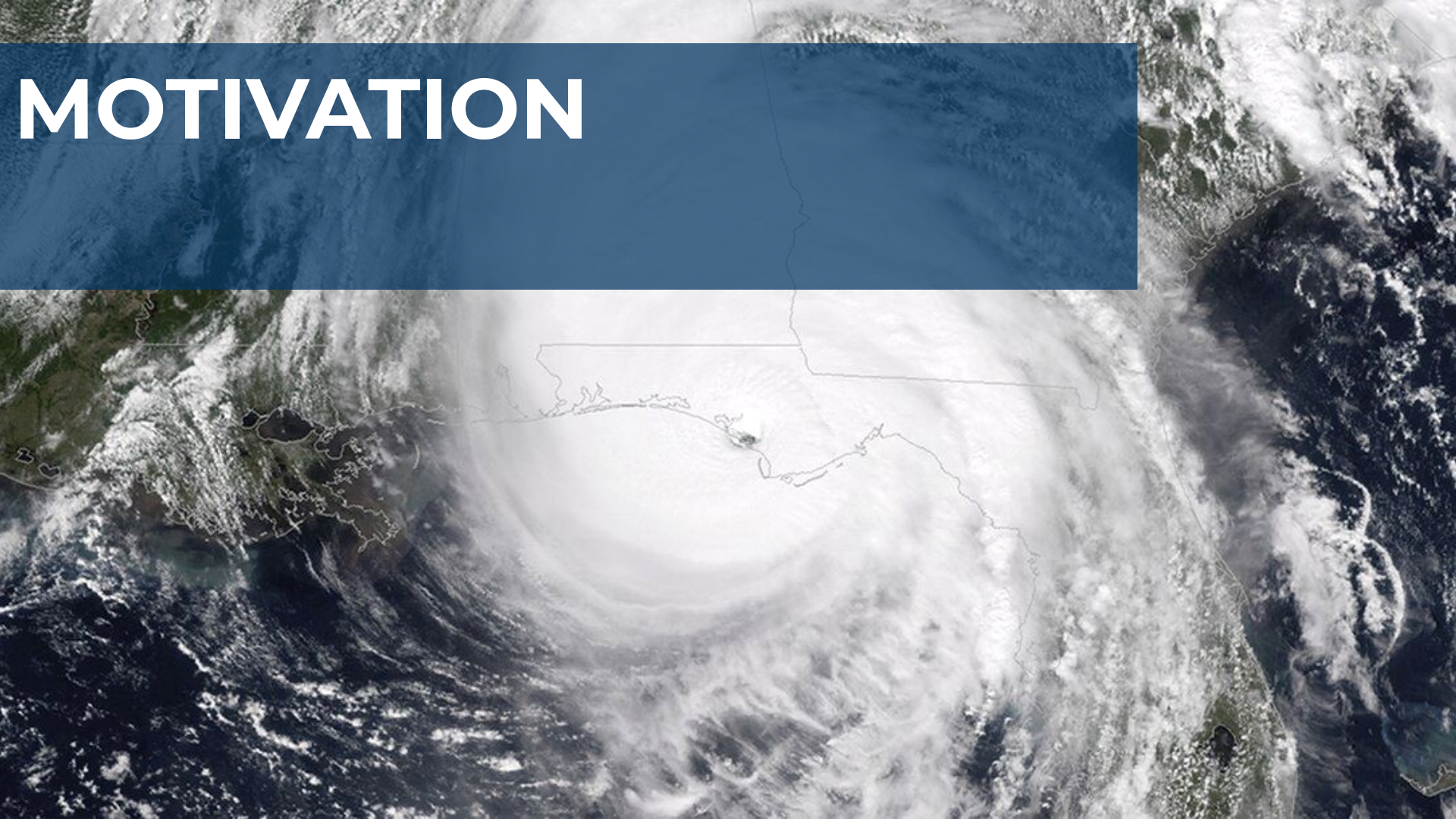
TCORF/IHC | MARCH 9, 2022

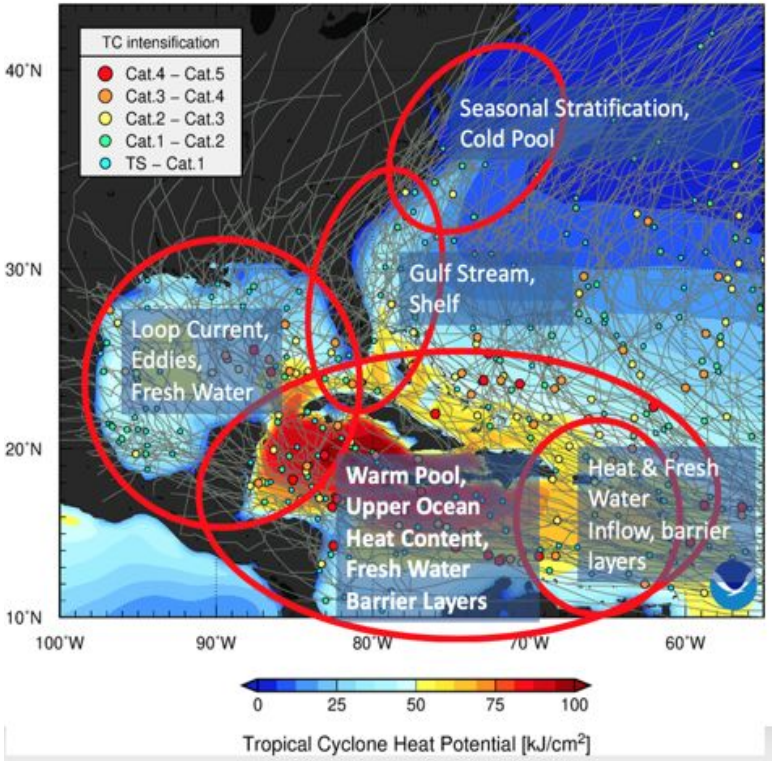
MOTIVATION



HOW TCs IMPACT THE OCEAN

Temperature and salinity response:

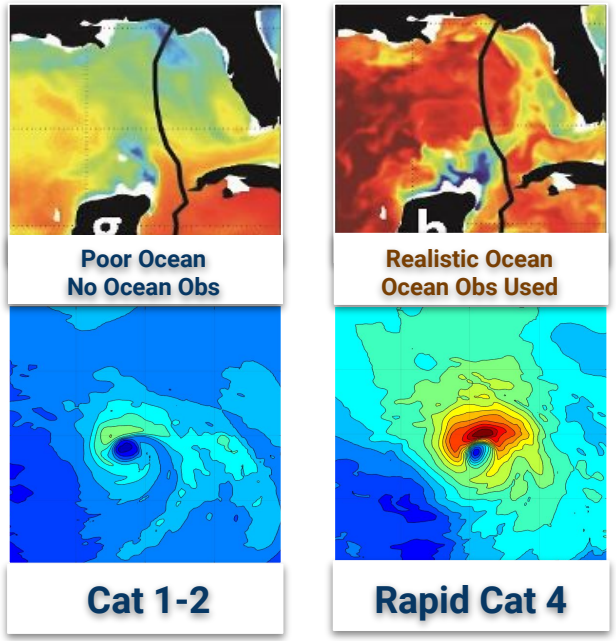
- TCs **deepen** the upper ocean mixed layer, **cool** the sea surface and **warm** the subsurface
- Sea surface loses heat through **air–sea heat flux**, there is also a significant mixing effect for the sea surface cooling
- Freshness of the sea surface by precipitation **increases the upper ocean stratification** and **weakens the TC-induced mixing**



Zhang et al. 2021

IMPORTANCE OF REPRESENTING THE OCEAN

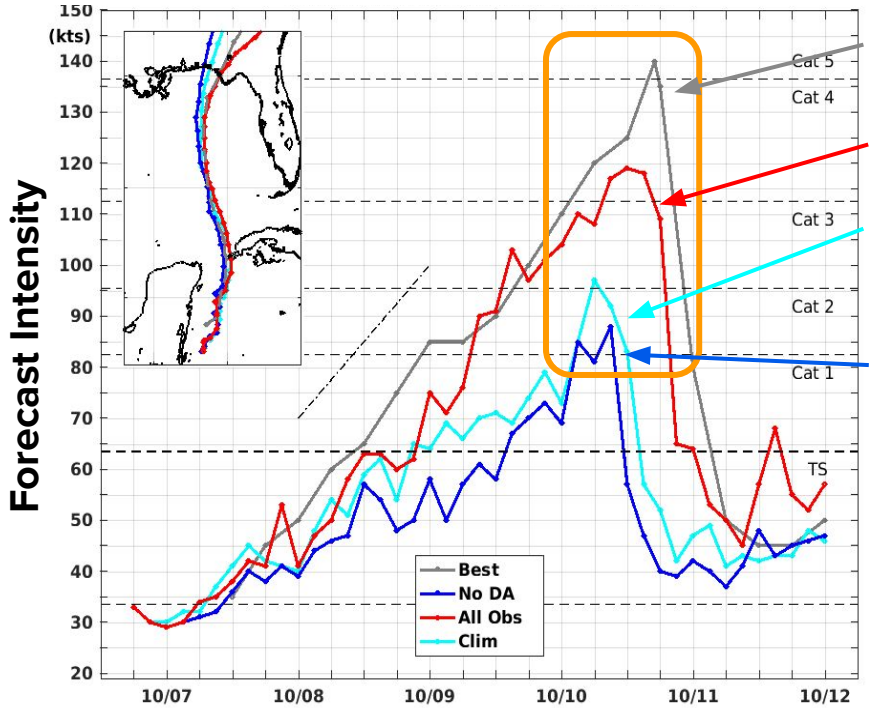
HURRICANE MICHAEL (2018)



Le Henaff et al. 2021

- Decades of research and operational activities conducted by NOAA and our partners have solidified the **ocean as a key component** of the tropical cyclone (TC) intensity change
- Correctly representing the ocean can reduce intensity error by **over 50%**

IMPROVING FORECASTS THROUGH OCEAN DATA ASSIMILATION



Observed

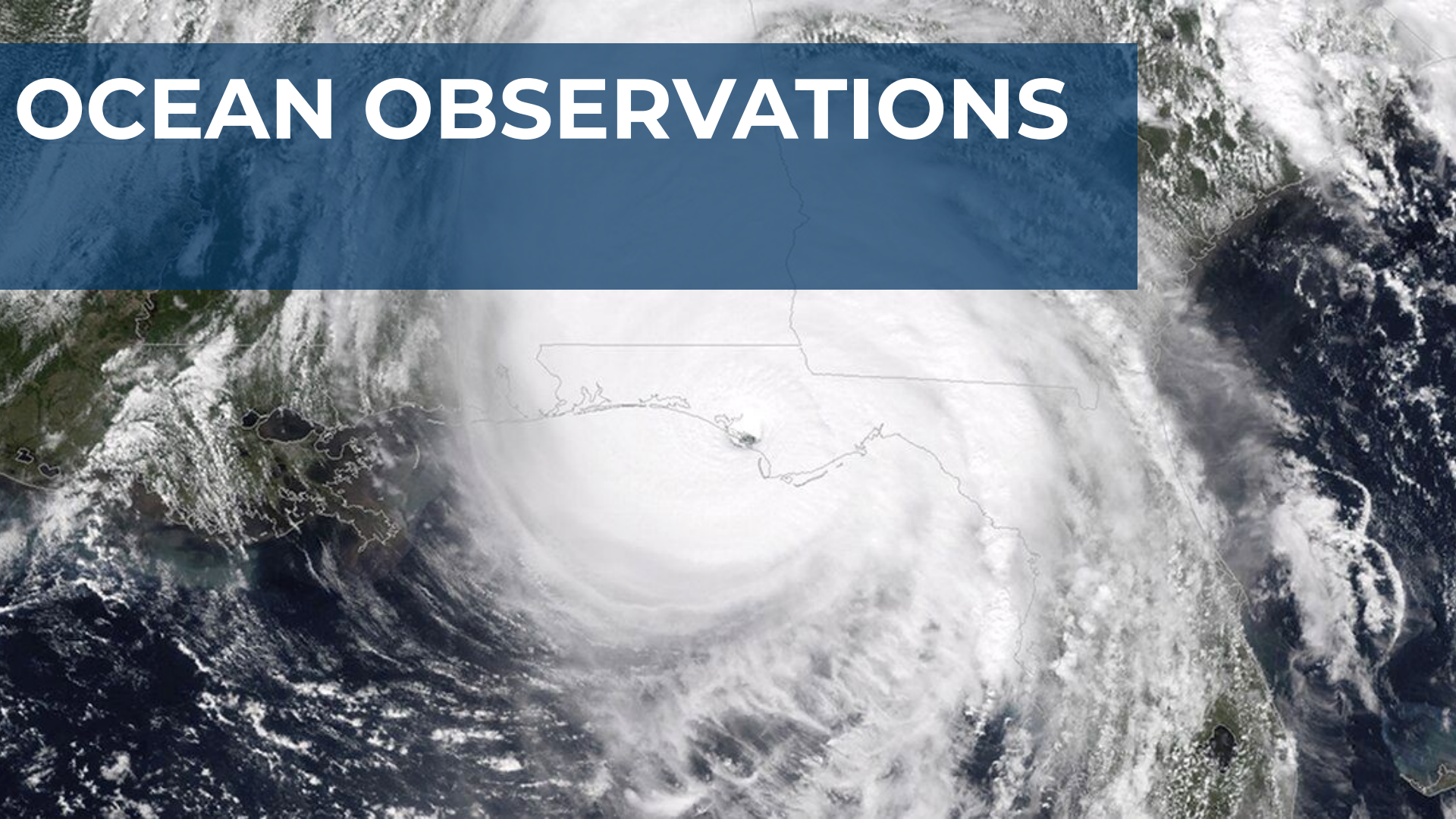
Assimilate Ocean Data

Use Climatology

Ignore Ocean Data

[Le Henaff et al. 2021](#)
Hurricane Michael (2018) OSE

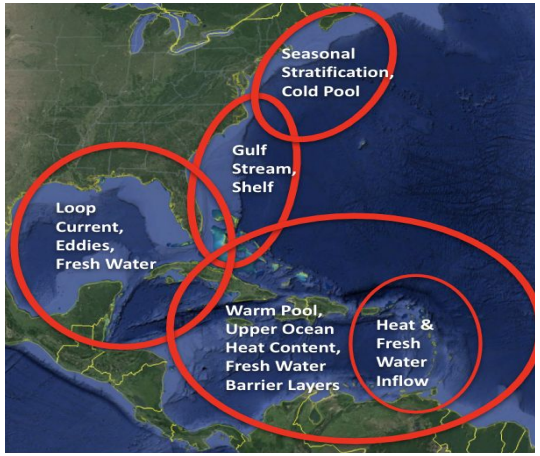
OCEAN OBSERVATIONS

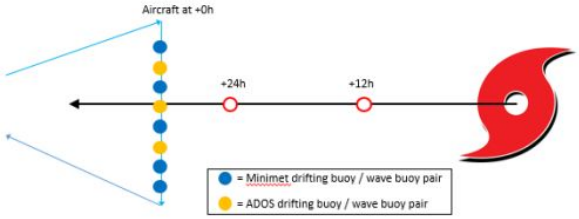


OCEAN OBSERVATIONS

- **GOAL**: provide ocean observations to improve how the ocean component is represented in hurricane forecast models
  - **Sustained mode**: when ocean observations are focused on the sustained monitoring of EOFs (e.g., ocean currents, gyres, global ocean heat content)
  - **Targeted mode**: when they are dedicated to assessing features known to be linked to hurricane intensity changes

Essential Ocean Features (EOFs)

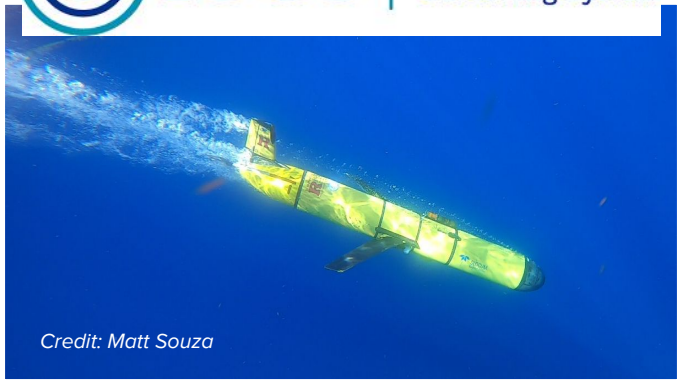




Example of targeted drifter deployments

UNDERWATER GLIDERS

IOOS | Integrated Ocean Observing System

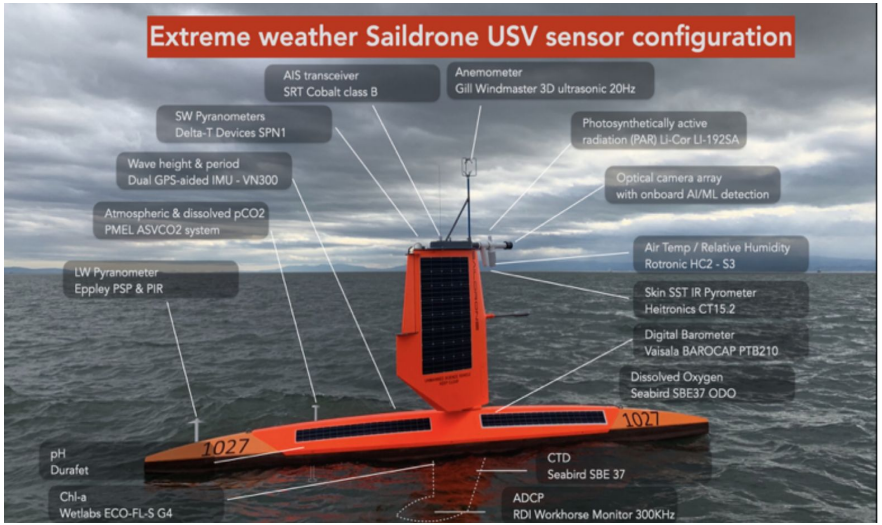


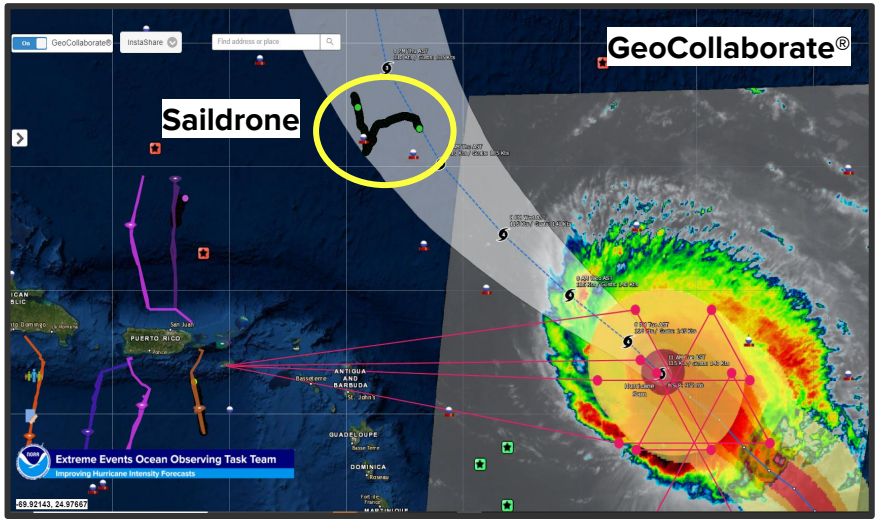
- Autonomous Underwater Vehicle (AUV)
  - Piloted from ground
- Profiles of **T, S, O_2, pH, CDOM**, surface and depth-average currents
- 5-20 dives per day to 200-1000 m depth
- Operate and transmit data under hurricane wind conditions; real-time data transmissions to GTS
- **44 Hurricane Glider missions in 2021 (U.S IOOS, IOOS RAs, Navy, etc.)**

https://oceanservice.noaa.gov/aa-updates/ioos-051619.html

SAILDRONE (UxS)

Observing the air-sea interface with Saildrones

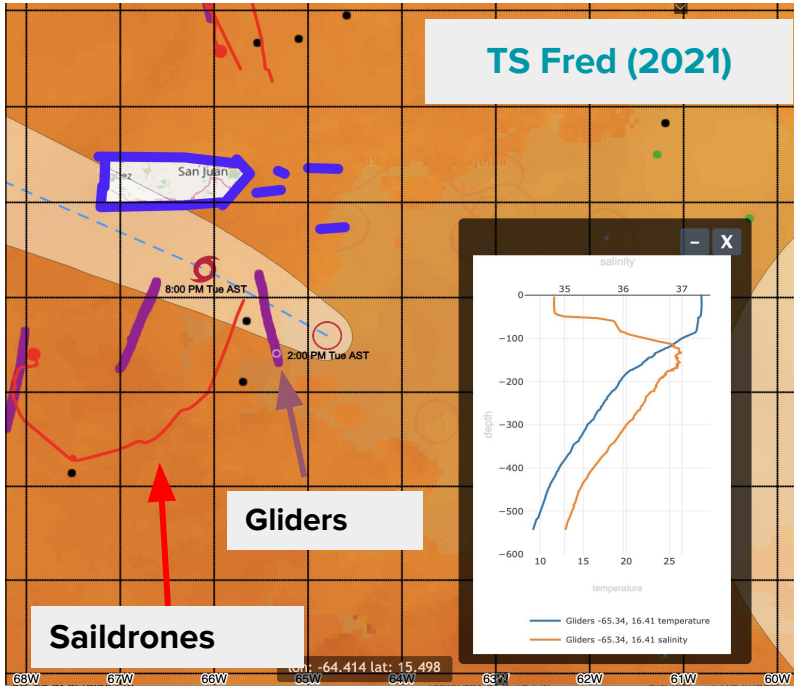




Participants: PMEL, AOML, UW, CIMAS, SECOORA, NESDIS CW

https://www.pmel.noaa.gov/saildrone-hurricane2021/

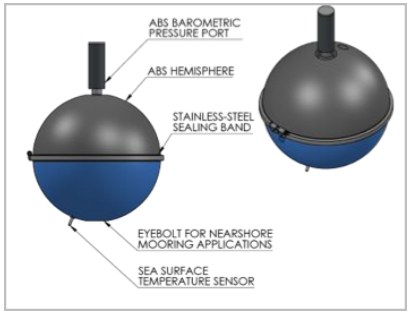
SAILDRONE-GLIDER PAIRS



- 5 saildrones operated for combined 502 days during the 2021 hurricane season
- **100 days of saildrone-glider co-located measurements**
  - 30 dropsondes also deployed near saildrones
- First air-sea measurements from an uncrewed surface ocean vehicle in a major hurricane (Sam)

https://www.pmel.noaa.gov/saildrone-hurricane2021/

DRIFTERS

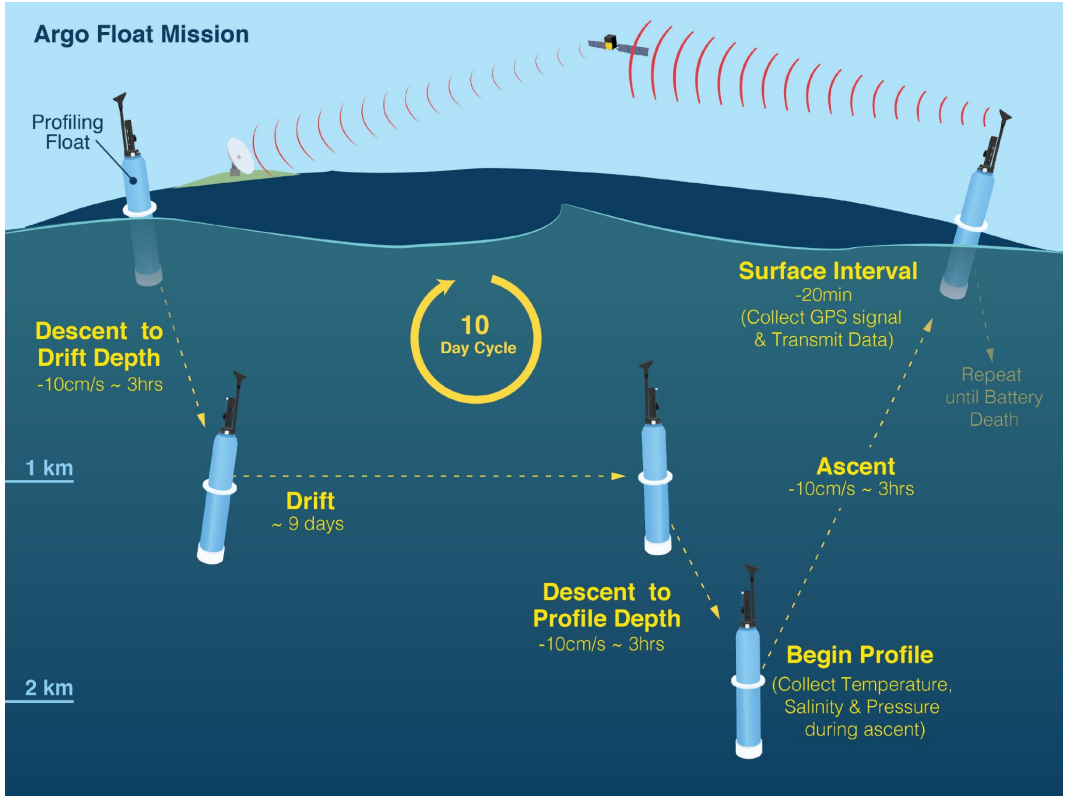


Credit: Scripps LDL

- **Satellite-tracked surface drifting buoys**
  - Provide accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature, atmospheric pressure, winds and salinity
  - Sustained and targeted (depending on type)
- Wave array deployments (2021) captured 3 hurricanes and 2 tropical storms with Directional Spectra Wave Drifters (DWSD)
- **A-sized *Directional Wave Spectra Drifters*** initial tests courtesy of AOC

https://gdp.ucsd.edu/ldl/global-drifter-program/

ARGO FLOATS



- Sustained array of Argo floats are dispersed throughout the Gulf of Mexico and the Atlantic
- Provide valuable T, S, and P profiles during cycling
- **Rapid cycling** (2.5 days) piloted during the 2021 hurricane season

https://globalocean.noaa.gov/Research/Argo-Program

ALAMO FLOATS

Credit: Steve Jayne, WHOI

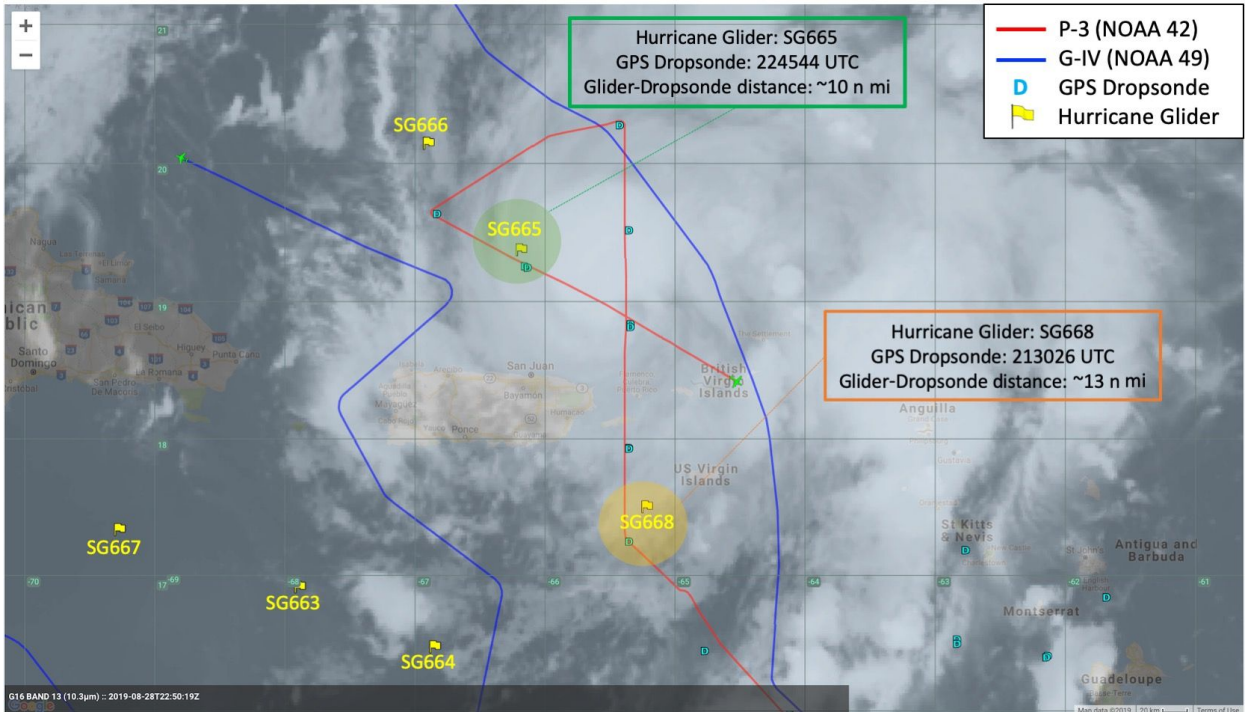
- **A**ir **L**aunched **A**utonomous **M**icro **O**bserver (ALAMO)
- Smaller profiling float that can be deployed through the chute installed in the back of a plane
  - Smaller Argo-style float that will fit in the AXBT launcher
  - Capable of 100 – 150 profiles to 1000m
- 7 Successful ALAMO deployments from the C-130 during 2021 season

https://alamo.whoi.edu/

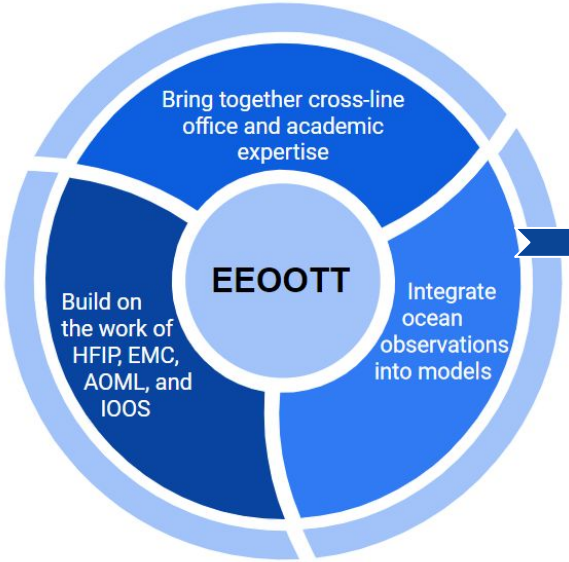
COORDINATION

Hurricane Dorian (2019) Dropsondes – Glider Coordination

NOAA Hurricane Glider – NOAA P-3 GPS Dropsonde Coordination



EXTREME EVENTS OCEAN OBSERVATIONS TASK TEAM



Priority Recommendations:

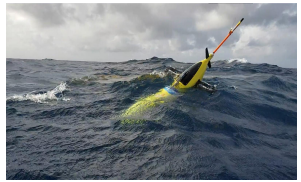
Coordinate observations

Evaluate observation impacts

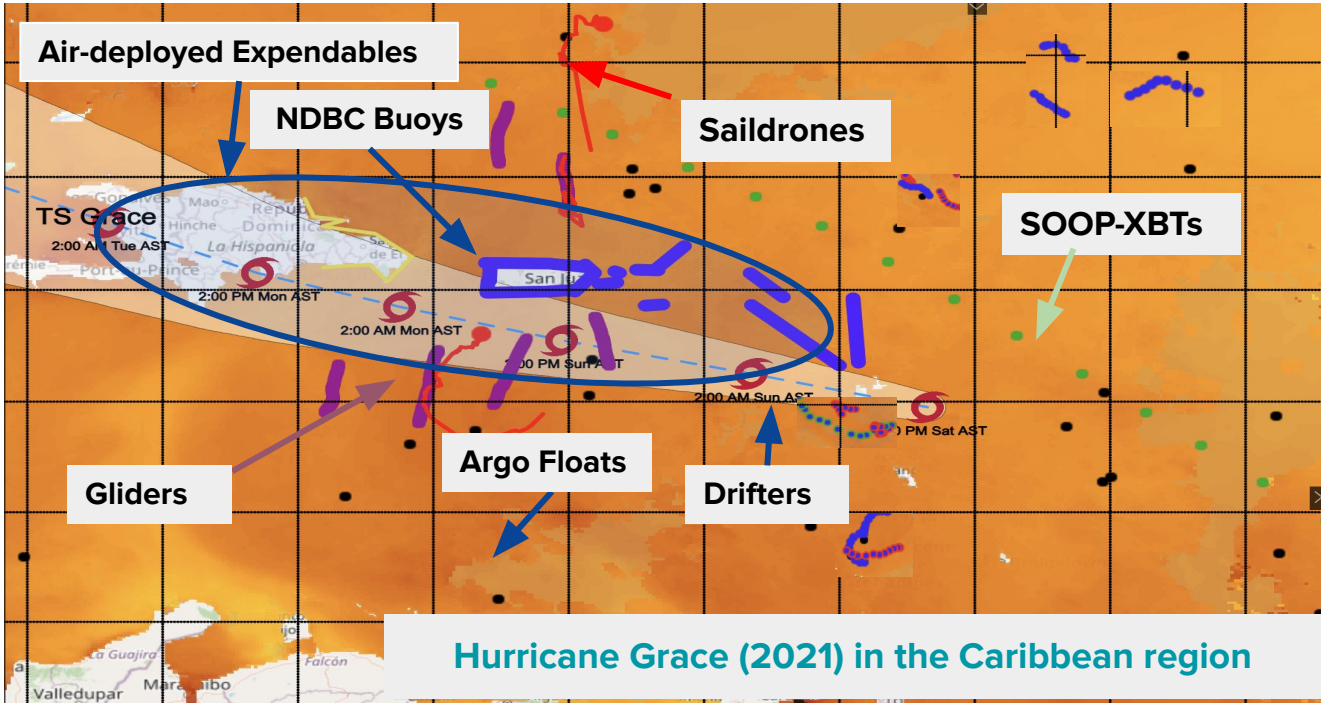
Improve data assimilation

Prioritize for future operations

COORDINATED OCEAN OBSERVING



https://cwcgom.aoml.noaa.gov/cgom/OceanViewer/index_phod.html



Hurricane Grace (2021) in the Caribbean region

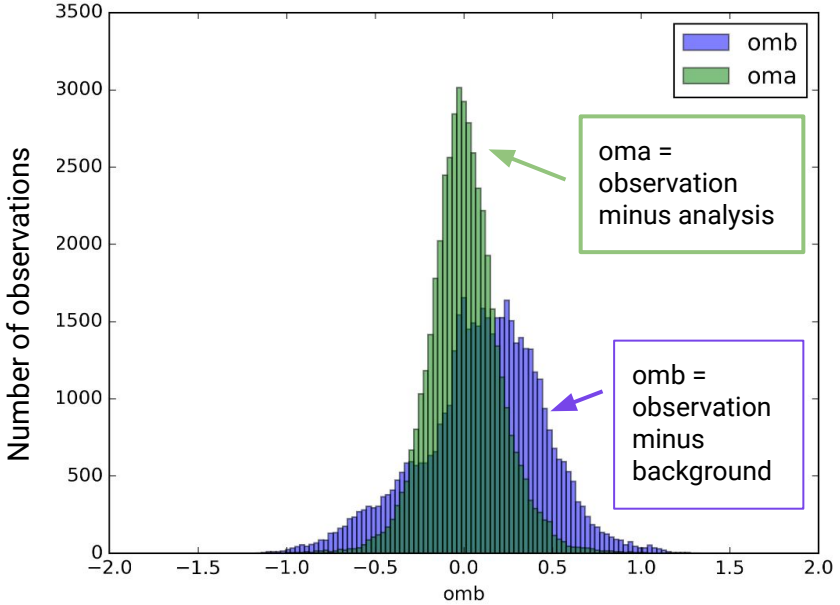
ASSESSING OBSERVING SYSTEM DESIGN

- Highlight the importance of sustained ocean observations on improving **operational ocean** and **coupled atmosphere-ocean** models

- Perform **Observing System Simulation Experiments** (OSSEs) and **Observing System Experiments** (OSEs)

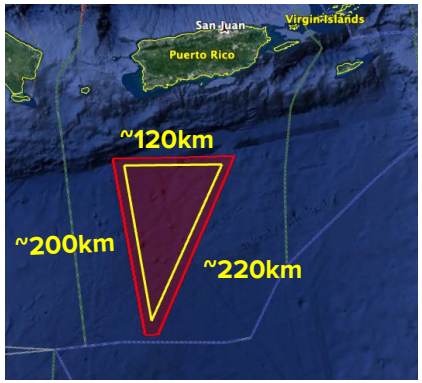
- Desired outcome: design and propose to NOAA an **integrated ocean observing** system that has an **optimal impact** on the forecast models

Example: impact of glider profiles improving data assimilation for *Hurricane Isaias*

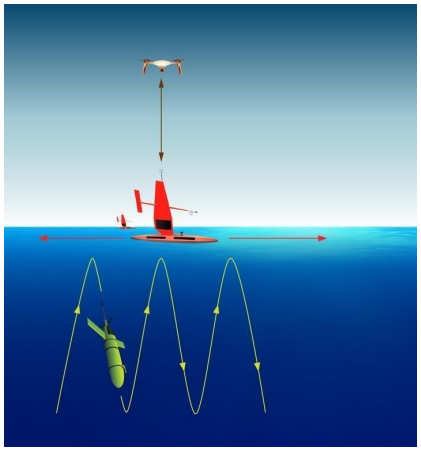


Credit: Ling Liu, Jong Kim, Cameron Book and HeeSook Kang [NOAA IMPACT]

FUTURE PLANS: COMBINING CAPABILITIES



Glider = Yellow
Saildrone = Red



Source: NOAA/PMEL

- Planning for an integrated field experiment
- **Co-located and quasi simultaneous observations of the full air-sea transition zone with autonomous vehicles**
  - Atmospheric boundary layer: small Uncrewed Aircraft Systems (sUAS)
  - Air-sea interface: Saildrone
  - Upper ocean: Gliders
- Supplement with **sustained observations** to improve initial conditions (Argo, drifters, gliders) and **targeted observations** (aircraft instruments, expendables, etc.) before/during/after a storm

SUMMARY

- Highlighting the need to accurately **represent the ocean component** (to complement the atmosphere) and better observe & understand the **air-sea transition zone**
- Working to increase the **situational awareness** of the types of ocean observations available to highlight **opportunities for colocated observations** from aircrafts, expendables, etc.
- Continue evaluating the **impact** of these various observations on the models
- Continue building a **foundation** for a future sustained observing system for hurricane research and forecasts

PARTNERS

HFIP | HURRICANE FORECAST IMPROVEMENT PROGRAM

Scripps Institution of Oceanography's
LAGRANGIAN DRIFTER LABORATORY

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

Global Ocean Monitoring and Observing
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

GeoCollaborate

CIMAS

IOOS | Integrated Ocean Observing System

Argo

WEATHER PROGRAM OFFICE

PMEL

ATLANTIC OCEANOGRAPHIC & METEOROLOGICAL LABORATORY NOAA

MARACOOS
Ocean Information for a Changing World
Mid-Atlantic Regional Association Coastal Ocean Observing System

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

OCOVI
Ocean and Coastal Observing Virgin Islands
www.ocovi.org

GCOOS
GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM

NATIONAL WEATHER SERVICE

PREDICTION OCEAN NOAA CENTER
The Mariner's Weather Lifeline

NOAA NESDIS STAR
Center for Satellite Applications and Research
SMCD CORP SOCD

CARICOOS

SECOORA
Southeast Coastal Ocean Observing Regional Association

CoastWatch

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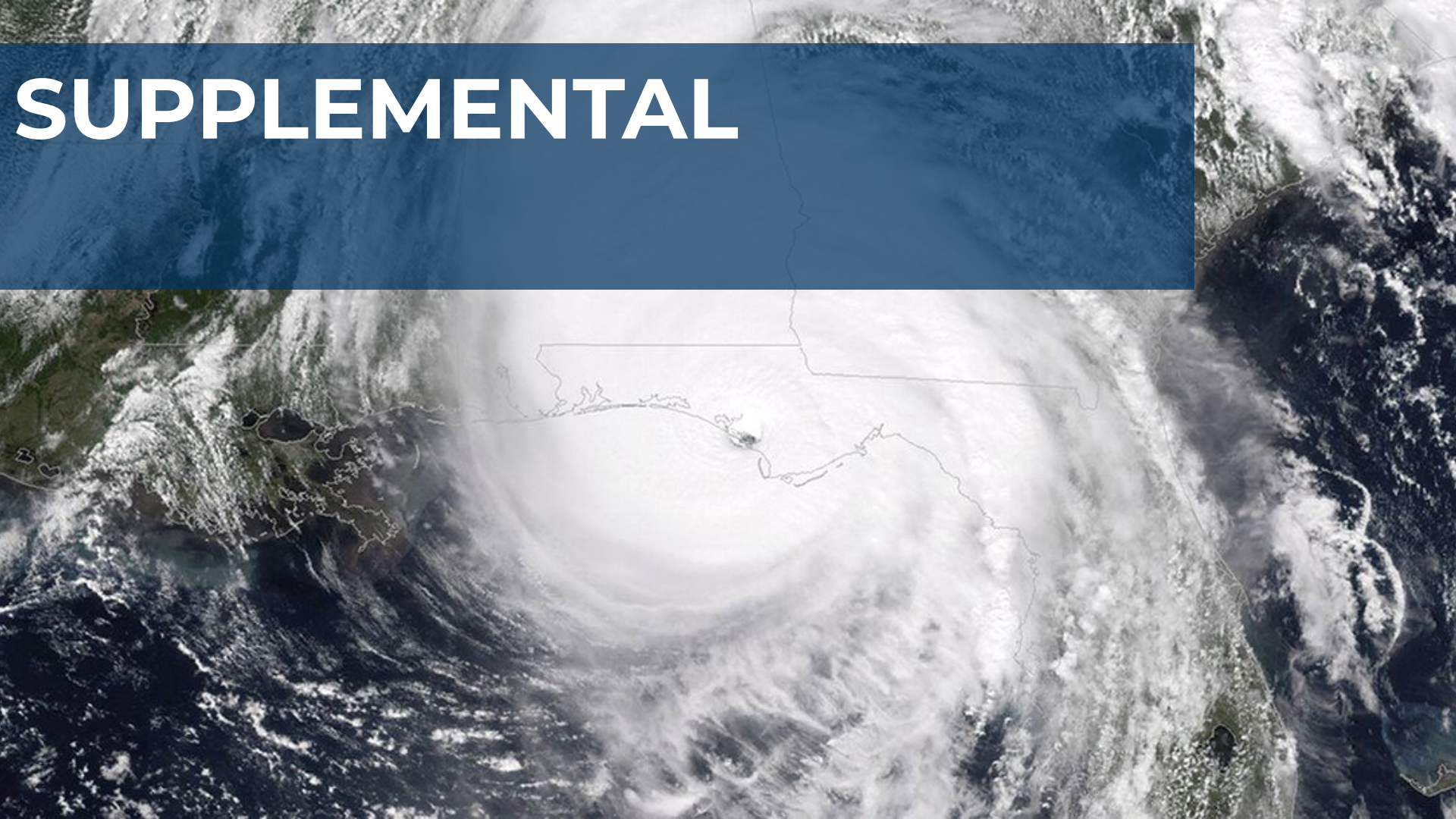
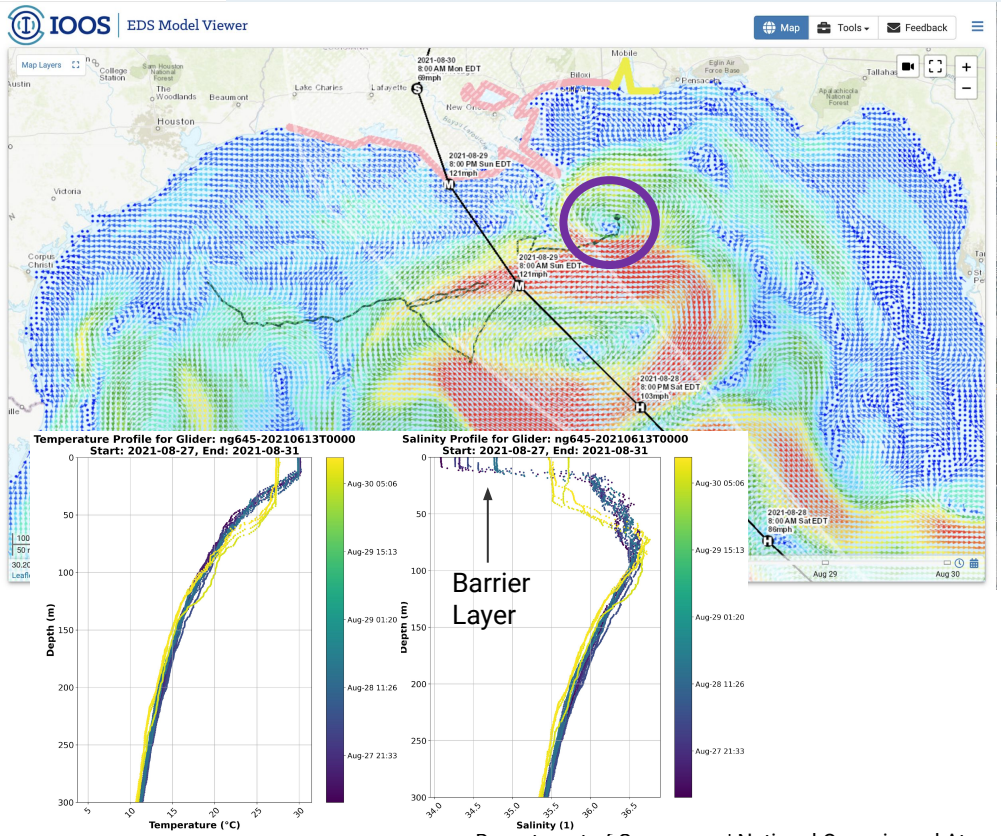
SUPPLEMENTAL



HURRICANE IDA (2021)

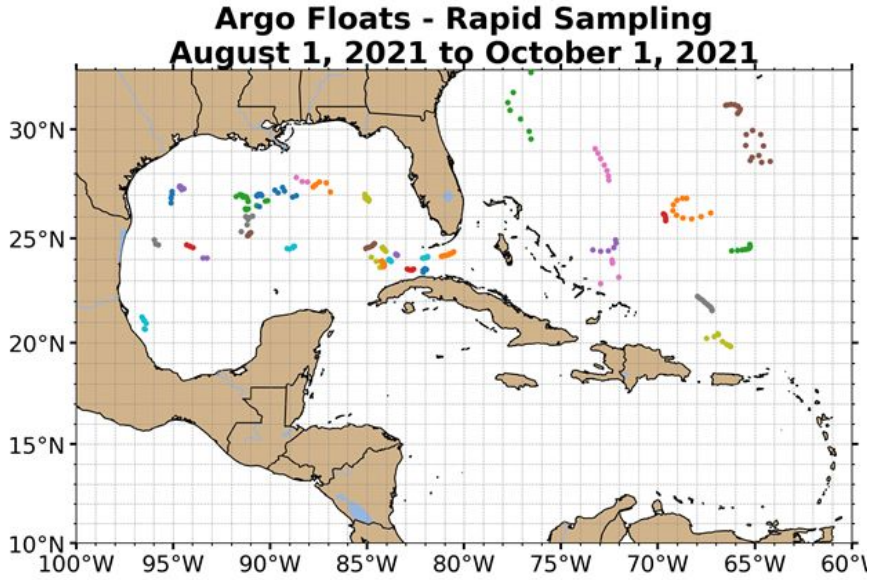


- Importance of **capturing fresh water barrier layers** and ensuring their accurate representation in the models (RTOFS, GOFS), as well as the importance of **coastal/shelf observations**
- Ocean conditions (Loop Current) kept Ida strong, and favored **intensification**

Credit: Rutgers University

ARGO FLOATS + IMPACTS ON MODELS

- 50 Argo floats in the Gulf of Mexico and Caribbean were *rapid cycling*
- Rutgers is currently working to assess the impact of these rapidly cycled floats on RTOFS - which is used to initialize the coupled operational hurricane forecast models
- Beneficial for **better understanding T, S, OHC, potential energy anomalies**, etc. throughout the season and in advance of an approaching storm



Credit: Rutgers